Non-Contact Free Carrier Density Measurements for Compound Semiconductors

NIST is systematically addressing issues that are central to determining the accuracy and precision of Raman spectroscopy for use in semiconductor manufacturing. Key technical issues involved include; the semiconductor under investigation, the measurement system parameters, and the Raman spectral model used to fit the measured spectra.

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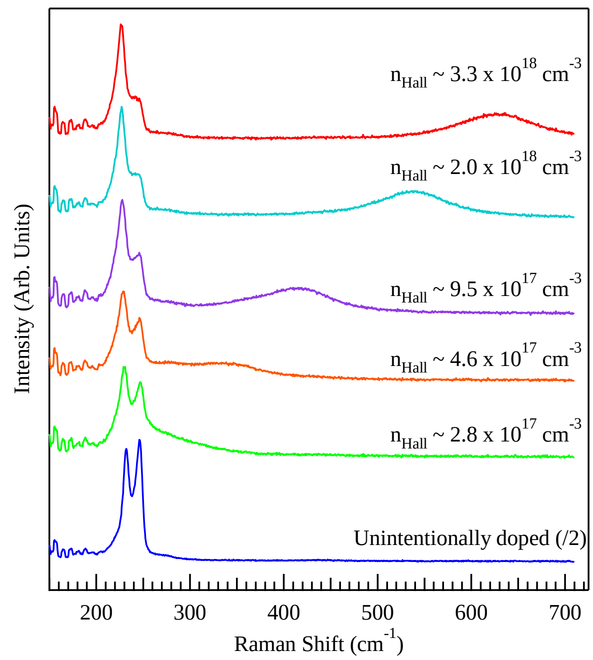
Transport of carriers is central to the operation of all optoelectronic devices and reliable measurement of the carrier properties is critical. Hall or capacitance-voltage measurements are traditionally used to obtain this information, but require electrical contact. This precludes the use of these techniques *in situ* during growth or processing and, typically, even on actual device layers. Raman spectroscopy, as an optical technique that can be used for transport property determination, does not suffer from these limitations. In addition, it is non-destructive, spatially resolved, and can be applied to a specific buried layer, which is sometimes a problem for traditional electrical measurements.

The purpose of this work is to develop non-contact measurement methods for carrier concentration and mobility in optoelectronic materials. Materials with a range of properties suitable for use in a variety of optoelectronic devices operating at different regions of the electromagnetic spectrum are being investigated. The primary focus is on narrow band gap group III-antimonide materials and wide band gap group III-nitride materials. Spectroscopic systems were optimized for each material system after examining selected thin films of narrow band gap GaSb, GaAsSb, GaInSb, and GaInAsSb and wide band gap GaN, and AlGaN, obtained from various collaborators. Systematic Raman spectroscopic measurements have been performed on epitaxial layers of GaSb, GaInAsSb, GaAs, InP, and GaN with various doping levels and types. An example of a series of Raman spectra is shown in ***Figure 1.*** Spectral models of various levels of sophistication have been developed for n-type doped GaSb, p-type GaSb, n-type GaInAsSb, p-type GaInAsSb, and n-type GaN. Modeling of the Raman spectra from the different materials requires different spectral models that account for the differences in physical properties that make these materials suitable for different applications. In depth comparisons of the carrier concentrations determined from spectral models to the carrier concentrations determined from Hall effect measurements have been performed for n-type doped GaSb, p-type GaSb and n-type GaInAsSb.

The NIST work should facilitate the utilization of Raman spectroscopy for spatially resolved, semiconductor off-line characterization as well as process monitoring and control during film growth and subsequent patterning processes.



Future Directions: In depth comparisons of the carrier concentrations determined from spectral models to the carrier concentrations determined from Hall effect measurements will be performed for p-type GaInAsSb and n-type GaN. In addition, this technique will be evaluated for use on doped GaN nanowires.

Publications:

J.E. Maslar, W.S. Hurst, and C.A. Wang, "*Raman Spectroscopy of n-Type and p-Type GaSb with Multiple Excitation Wavelengths,*" Applied Spectroscopy, submitted.

J.E. Maslar, W.S. Hurst, and C.A. Wang, "*Raman Spectroscopic Determination of Hole Concentration in p-Type GaSb,*" Journal of Applied Physics, submitted.